

WHAT IS CLAIMED IS:

1. A method for gasification of a carbonaceous material to a substantially nitrogen-free product gas, comprising the steps of:
  - providing a source of oxygen-enriched gas containing less than about 20 mole percent nitrogen;
  - providing a source of water vapor;
  - pre-mixing said oxygen-enriched gas and water vapor to form a substantially homogeneous mixture;
  - contacting said substantially homogeneous mixture with a substantially ash-free carbonaceous fuel at substantially stoichiometric ratio in a high turbulence burner having one of an aerodynamic and a bluff body flame holder to promote the formation of free radical species of the combustion products at an adiabatic flame temperature exceeding about 2400°C (1316°C);
  - wherein an ultra-superheated steam (USS) composition is produced comprising a mixture of superheated water vapor, carbon dioxide and free radicals with less than about 3.0 mole percent free oxygen;

25 recovering and directing said ultra-superheated steam  
26 (USS) composition to a gasification reactor  
27 wherein a carbonaceous material is reacted with  
28 said ultra-superheated steam (USS) composition to  
form a product gas.

1 2. A method in accordance with claim 1, wherein said  
2 oxygen-enriched gas comprises at least about 80 mole  
3 percent oxygen.

1 3. A method in accordance with claim 1, wherein the  
2 homogeneous mixture of steam and oxygen-enriched gas  
3 comprises about 15 to about 40 mole percent oxygen.

1 4. A method in accordance with claim 1, wherein said  
2 carbonaceous fuel burned in said burner comprises at  
3 least one of a liquid petroleum product, gaseous  
4 hydrocarbon fuel, and a produced fuel gas.

1 5. A method in accordance with claim 1, wherein said  
2 carbonaceous fuel burned in said burner comprises  
3 product gas produced in said gasification reactor.

1 6. A method in accordance with claim 1, wherein the

2           quantity of oxygen in said substantially homogeneous  
3           mixture is substantially stoichiometric with respect to  
4           the quantity of substantially ash-free fuel.

1           7.   A method in accordance with claim 1, wherein at least  
2           one of said water vapor and oxygen is pre-heated prior  
3           to contact with said carbonaceous material.

1           8.   A method in accordance with claim 1, wherein said  
2           ultra-superheated steam (USS) composition has a  
3           temperature of about 2400°F (1316°C) to about 5000°F  
4           (2760°C).

1           9.   A method in accordance with claim 1, wherein said  
2           ultra-superheated steam (USS) is essentially clear and  
3           colorless.

1           10.  A method in accordance with claim 1, wherein said  
2           carbonaceous material is gasified at a reactor  
3           temperature of about 1200°F (649°C) to about 2200°F  
4           (1204°C).

1           11.  A method in accordance with claim 1, wherein said  
2           carbonaceous material comprises one of coal, coke,

biomass, liquid petroleum fraction, liquid cracking product, gaseous hydrocarbon and a refinery waste material.

12. A method in accordance with claim 1, wherein said produced fuel gas is substantially nitrogen-free.

13. A method in accordance with claim 1, wherein said carbonaceous material gasified by said ultrasuperheated steam comprises a mixture of a first carbonaceous material containing substantially no oxygen with a second carbonaceous material containing substantial oxygen.

14. A method in accordance with claim 13, wherein said first carbonaceous material comprises less than about 10 w/w % oxygen, and said second carbonaceous material comprises at least about 20 w/w % oxygen.

15. A method in accordance with claim 13, wherein said quantity of said second carbonaceous material to be mixed with said first carbonaceous material is determined by:  
(a) initiating and maintaining gasification in at least

6 one ratio of second carbonaceous material to said  
7 first carbonaceous material;

8 (b) determining the carbon dioxide content of the  
9 outlet gas at each ratio of second carbonaceous  
10 material to said first carbonaceous material;

11 (c) comparing each determined carbon dioxide content  
12 with a minimum controllable positive preset value  
13 thereof; and

14 (d) iterating steps (a) through (c) with increasing  
15 ratios of said second carbonaceous material to  
16 said first carbonaceous material until said  
17 desired minimum controllable positive preset value  
18 of carbon dioxide content is substantially  
19 attained.

20  
21 16. A method in accordance with claim 15, wherein said  
22 ratio of second carbonaceous material to said first  
23 carbonaceous material is adjusted to maintain a  
24 continuous gasification process at substantially said  
25 minimum controllable positive preset value of carbon  
26 dioxide content in said product gas.

27 17. A method in accordance with claim 15, wherein the mole  
28 percent of carbon dioxide in said product gas is

3 maintained at a value less than about 1-10 mole  
4 percent.

1 18. A method in accordance with claim 13, wherein said  
2 quantity of said second carbonaceous material to be  
3 mixed with said first carbonaceous material is  
4 determined by:

- 5 (a) initiating and maintaining gasification in at least  
6 one ratio of second carbonaceous material to said  
7 first carbonaceous material;  
8 (b) determining the free water content of the outlet  
9 gas at each ratio of second carbonaceous material  
10 to said first carbonaceous material;  
11 (c) comparing each determined free water content with a  
12 minimum controllable positive preset value  
13 thereof; and  
14 (d) iterating steps (a) through (c) with increasing  
15 ratios of said second carbonaceous material to  
16 said first carbonaceous material until said  
17 minimum controllable positive preset value of free  
18 water content is substantially attained.

1 19. A method in accordance with claim 18, wherein said  
2 ratio of second carbonaceous material to said first

3 carbonaceous material is adjusted to maintain a  
4 continuous gasification process at substantially said  
5 minimum controllable positive preset value of free  
6 water content in said product gas.

1 20. A method in accordance with claim 18, wherein the mole  
2 percent of free water in said product gas is maintained  
3 at a value less than about 1-10 mole percent.

1 21. A method in accordance with claim 13, wherein said  
2 first carbonaceous material comprises one of coal and a  
3 hydrocarbon.

1 22. A method in accordance with claim 13, wherein said  
2 second carbonaceous material comprises a cellulosic  
3 material.

1 23. A method in accordance with claim 13, wherein the first  
2 carbonaceous material comprises coal at about 85 w/w %  
3 to about 98 w/w % concentration, and the second  
4 carbonaceous material comprises a cellulosic material  
5 at about 2 w/w percent to about 15 w/w percent  
6 concentration.

1       24. A method in accordance with claim 13, wherein the first  
2       carbonaceous material comprises coal at about 10 w/w %  
3       to about 60 w/w % concentration, and the second  
4       carbonaceous material comprises a cellulosic material  
5       at about 40 w/w percent to about 90 w/w percent  
6       concentration.

1       25. A method for producing an ultra-superheated steam  
2       composition, comprising the steps of:  
3       providing a source of oxygen-enriched gas;  
4       providing a source of water vapor;  
5       pre-mixing said oxygen-enriched gas and water vapor  
6       from said sources to form a substantially  
7       homogeneous mixture; and  
8       contacting said substantially homogeneous mixture with  
9       a substantially ash-free fuel in a high turbulence  
10      burner with one of an aerodynamic and bluff body  
11      flame holder to promote the formation of free  
12      radical species of burner combustion products at  
13      an adiabatic flame temperature of at least about  
14      2400°F (1316°C);  
15      whereby an ultra-superheated steam composition is  
16      produced in said burner comprising a mixture of  
17      superheated water vapor, carbon dioxide and free



18 radicals with less than about 3.0 mole percent  
19 free oxygen;  
20 wherein said ultra-superheated steam composition has a  
21 temperature of at least about 2400°F (1316°C).

1 26. A method in accordance with claim 25, wherein said  
2 oxygen-enriched gas comprises at least about 80 mole  
3 percent oxygen.

1 27. A method in accordance with claim 25, wherein the  
2 homogeneous mixture of steam and oxygen-enriched gas  
3 comprises about 15 to about 40 mole percent oxygen.

1 28. A method in accordance with claim 25, wherein the  
2 substantially ash-free fuel comprises one of a  
3 petroleum-based liquid, hydrocarbon containing gas, and  
4 a produced fuel gas from a gasification process.

1 29. A method in accordance with claim 25, wherein the  
2 quantity of oxygen in said substantially homogeneous  
3 mixture is substantially stoichiometric with respect to  
4 the quantity of substantially ash-free fuel.

1 30. A method in accordance with claim 25, wherein at least

2 one of said water vapor and oxygen is pre-heated prior  
3 to contacting with said substantially ash-free fuel.

1 31. A method in accordance with claim 25, wherein the  
2 ultra-superheated steam (USS) is produced at an  
3 adiabatic flame temperature of between about 2400°F  
4 (1316°C) and about 5000°F (2760°C).

1 32. A method in accordance with claim 25, wherein the  
2 ultra-superheated steam is produced in a clear  
3 colorless flame.

1 33. A method in accordance with claim 25, wherein said  
2 produced fuel gas is substantially nitrogen-free.

1 34. A method in accordance with claim 25, further  
2 comprising the step of collecting and directing said  
3 ultra-superheated steam (USS) to an industrial process.

1 35. A method in accordance with claim 34, wherein said  
2 industrial process comprises a gasification process in  
3 which a carbonaceous material is converted to a fuel  
4 gas containing substantially CO and H<sub>2</sub>.

1        36. A method in accordance with claim 35, wherein said  
2                substantially ash-free fuel comprises a portion of the  
3                fuel gas produced by said gasification process.

1        37. In a gasification apparatus for gasifying a  
2                carbonaceous material to a product gas with an ultra-  
3                superheated steam (USS) composition in a reactor, the  
4                ultra-superheated steam formed in a high turbulence  
5                burner with an aerodynamic flame holder at an adiabatic  
6                flame temperature of between about 2400°F (1316°C) and  
7                about 5000°F (2760°C) by combustion of a substantially  
8                ash-free fuel with a pre-mixture of oxygen and water  
9                vapor; wherein a method for controlling the temperature  
10               of the gasification product gas comprises:

11               controlling the ratio of (a) oxygen in said pre-mixture  
12                        to (b) said carbonaceous fuel fed to the burner at  
13                        a near-stoichiometric value to limit free oxygen  
14                        in the ultra-superheated steam composition to a  
15                        value generally less than about 3.0 mole percent;  
16                        and

17               controlling the rate of oxygen and substantially ash-  
18                        free fuel in said pre-mixture, whereby the  
19                        temperature of said product gas is controlled at a  
20                        preset temperature between about 1200°F (649°C)

21 and about 2200°F (1204°C).

1 38. In a gasification apparatus for gasifying a  
2 carbonaceous material to a product gas with an ultra-  
3 superheated steam (USS) composition in a reactor, the  
4 ultra-superheated steam formed in a high turbulence  
5 burner with an aerodynamic flame holder at a an  
6 adiabatic flame temperature of between about 2400°F  
7 (1316°C) and about 5000°F (2760°C) by combustion of a  
8 substantially ash-free carbonaceous fuel with a pre-  
9 mixture of oxygen and water vapor; wherein a method for  
10 controlling the temperature of the gasification product  
11 gas comprises:  
12 controlling the ratio of (a) oxygen in said pre-mixture  
13 to (b) said carbonaceous fuel fed to the burner at  
14 a near-stoichiometric value to limit free oxygen  
15 in the ultra-superheated steam composition at a  
16 value generally less than about 3.0 mole percent;  
17 controlling the rate of ultra-superheated steam  
18 composition at a substantially constant value; and  
19 controlling the rate of carbonaceous material fed to  
20 said gasification reactor to control the  
21 temperature of said product gas at a preset  
22 temperature between about 1200°F (649°C) and about

23                    2200°F (1204°C).

1            39. A method for increasing the efficiency of a thermal  
2            gasification of a first carbonaceous material  
3            substantially comprising elemental carbon in a  
4            gasification reactor, said method comprising the steps  
5            of:  
6            determining a quantity of a second carbonaceous  
7            material containing oxygen to be combined with  
8            said first carbonaceous material for optimal  
9            gasification; and  
10           combining said determined quantity of said second  
11           carbonaceous material with said first carbonaceous  
12           material; and  
13           gasifying said combined first carbonaceous material and  
14           second carbonaceous material containing oxygen in  
15           said reactor to produce a product gas.

1           40. A method in accordance with claim 39, wherein said  
2           quantity of said second carbonaceous material to be  
3           combined with said first carbonaceous material is  
4           determined by:  
5           (a) initiating and maintaining gasification in at least  
6           one ratio of second carbonaceous material to said

- 7 first carbonaceous material to produce a product  
8 gas;
- 9 (b) determining the carbon dioxide content of the  
10 reactor outlet gas at each ratio of said second  
11 carbonaceous material to said first carbonaceous  
12 material;
- 13 (c) predetermining a desirable controllable minimally  
14 positive value of carbon dioxide in said reactor  
15 outlet gas;
- 16 (d) comparing each determined carbon dioxide content  
17 with said predetermined minimally positive value  
18 of carbon dioxide; and
- 19 (e) iterating steps (a) through (c) with increasing  
20 ratios of said second carbonaceous material to  
21 said first carbonaceous material until said  
22 predetermined controllable minimally positive  
23 value is substantially attained.

1 41. A method in accordance with claim 40, wherein the  
2 desired quantity of second carbonaceous material added  
3 to said first carbonaceous material at said  
4 predetermined controllable minimally positive value of  
5 carbon dioxide is between about 5 percent and about 25  
6 percent by weight.

1 42. A method for increasing the efficiency of a thermal  
2 gasification of a second carbonaceous material  
3 containing substantial oxygen in a gasification  
4 reactor, comprising the steps of:  
5 determining a quantity of a first carbonaceous material  
6 substantially comprising elemental carbon to be  
7 combined with said second carbonaceous material  
8 for optimal gasification; and  
9 gasifying said quantity of second carbonaceous material  
10 and said first carbonaceous material in said  
11 reactor.

1 43. A method in accordance with claim 42, wherein said  
2 quantity of first carbonaceous material to be combined  
3 with said second carbonaceous material is determined  
4 by:  
5 (a) initiating and maintaining gasification in at least  
6 one ratio of first carbonaceous material to said  
7 second carbonaceous material;  
8 (b) determining the carbon dioxide content of the  
9 reactor outlet gas at each ratio of first  
10 carbonaceous material to said second carbonaceous  
11 material;

- 12 (c) predetermining a desirable controllable minimally  
13 positive value of carbon dioxide in said reactor  
14 outlet gas;  
15 (d) comparing each determined carbon dioxide content  
16 with said predetermined minimally positive value  
17 of carbon dioxide; and  
18 (e) iterating steps (a) through (c) with increasing  
19 ratios of said first carbonaceous material to said  
20 second carbonaceous material until said  
21 predetermined controllable minimally positive  
22 value is substantially attained.

1 44. A method in accordance with claim 43, wherein the  
2 desired quantity of first carbonaceous material added  
3 to said second carbonaceous material at said  
4 predetermined controllable minimally positive value of  
5 carbon dioxide is between about 5 percent and about 50  
6 percent by weight.

1 45. A method for reducing oxygen consumption per unit  
2 produced fuel gas in an oxygen-blown gasification  
3 process gasifying a first carbonaceous material  
4 substantially comprising elemental carbon to a  
5 substantially nitrogen-free product gas, said method



6 comprising:  
7 adding a second carbonaceous material substantially  
8 comprising cellulose to said first carbonaceous  
9 material at about 5 w/w percent to about 25 w/w  
10 percent thereof; and  
11 gasifying the mixture of elemental carbon and  
12 cellulosic material at an elevated temperature.

1 46. A method for reducing oxygen consumption per unit  
2 produced fuel gas in an oxygen-blown gasification  
3 process gasifying a first carbonaceous material  
4 containing cellulose to a substantially nitrogen-free  
5 product gas, said method comprising:  
6 adding a second carbonaceous material substantially  
7 comprising elemental carbon to said first  
8 carbonaceous material at about 5 w/w percent to  
9 about 50 w/w percent; and  
10 gasifying the mixture of elemental carbon and  
11 cellulosic material at an elevated temperature.